Navy Case No. 84910

REDUCED SIZE TM CYLINDRICAL SHAPED MICROSTRIP ANTENNA ARRAY HAVING A GPS BAND STOP FILTER

This application is a continuation-in-part of U.S. Patent Application Serial No. 10/648,715, filed August 27, 2003

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to a microstrip antenna for use on a weapons system to transmit telemetry data. More specifically, the present invention relates to a reduced size TM cylindrical shaped microstrip antenna array having a GPS band stop filter which transmits telemetry data and which is adapted for use in a small area on a weapons system such as a missile.

2. Description of the Prior Art.

In the past microstrip antenna arrays which are used to transmit telemetry data from a weapons system to a ground station via an RF carrier signal, have required considerable space on board the weapons system to adequately separate the antenna feed network from the antenna elements which prevents the antenna feed network from becoming EM coupled to the antenna elements for the antenna array. Typically, when adequate space on the weapons system is not available, the microstrip antenna arrays have used multiple dielectric layers and feed lines have been placed on a lower layer so that

the feed line width can be made very narrow which results in reduced spacing to the antenna elements.

Now, however, there is a need to significantly reduce the size of the microstrip antenna elements and its feed network so that the microstrip antenna array can be used on a small diameter weapons systems.

There is also a need for a microstrip antenna which includes a band stop filter. The band stop filter operates in the L-Band frequency range to prevent GPS carrier signals from interfering with the transmission of telemetry data from the weapons system.

SUMMARY OF THE INVENTION

The present invention overcomes some of the difficulties of the past in that comprises a highly efficient microstrip antenna having an cylindrical shaped array of antenna elements which require considerably less space than other microstrip antenna arrays designed for use in confined spaces within a weapons system such as a missile, a smart bomb or the like.

The present invention comprises a TM cylindrical shaped microstrip antenna array which transmits telemetry data and which is adapted for use on weapons systems such as a missile

or smart bomb. The microstrip antenna operates at a TM frequency band of 2210 MHz +/- 2.5 MHz. The microstrip antenna is a Linear Polarized microstrip antenna with wrap around capability for a five inch diameter projectile and is constrained to a width of 1.5 inches. The microstrip antenna includes a six aligned copper antenna elements, and a copper etched feed network which provides for transmitted signals which are in phase and have equal amplitudes, and a depth of 0.5 inches. The RF output signal from a single 50-ohm output coaxial SMMB connector results in microstrip antenna 20 producing a quasi-omni directional radiation pattern with the roll plane cut at -4 dBi (-4 decibels) or better.

The TM cylindrical shaped microstrip antenna array has three stacked dielectric layers with the upper most dielectric layer comrpising a cover board, the middle layer comprising a circuit board and the bottom layer comprising a ground board. The circuit board includes six copper antenna elements on its upper surface, a first etched copper cross hatch pattern which is positioned in proximity to each of the six antenna elements, a feed network on its bottom surface and a second etched copper cross hatch pattern which is positioned in proximity to the feed network.

The ground board also has an etched copper cross hatch

pattern on its upper surface which aligns with the cross hatch pattern on te lower surface of the circuit board and a solid copper ground plane mounted on its lower surface.

Since the layout of the bottom surface of the circuit board is virtually identical to the layout of the upper surface of ground board, microwave signals will EM couple between dielectric layers even though there is a bonding film which separates the circuit board from the ground board. This unique feature of the mirostrip antenna array allows the vias or copper plated through holes on the circuit board to EM couple to the vias on the ground board thereby providing an electrical connection for the circuit board to the copper ground plane on the bottom surface of ground board.

An alternate embodiment of the present invention includes a GPS band stop filter which has a filter response of -60 dBi (-60 decibels) at 1575 MHz which is within the L-Band frequency range.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a side view of the reduced size TM cylindrical shaped microstrip antenna comprising the present invention;

FIG. 2 illustrates the top copper layer of a circuit board which includes the antenna elements for the reduced size TM

cylindrical shaped microstrip antenna comprising the present invention;

FIG. 3 is an exploded view taken along line 3-3 of FIG. 2 illustrating the tuning tabs and slot for each of the antenna elements and the copper cross hatch pattern for the circuit board of FIG. 2;

FIG. 4 illustrates the bottom copper layer of the circuit board of FIG. 2 which includes a feed network for the antenna elements of the microstrip antenna of FIG. 1;

FIG. 5 is an exploded view taken along line 5-5 of FIG. 4 illustrating the copper cross hatch pattern for the bottom copper layer of the circuit board of FIG. 4;

FIG. 6 illustrates the top copper layer of a ground board for the microstrip antenna comprising the present invention;

FIG. 7 is an exploded view taken along line 7-7 of FIG. 6 illustrating the copper cross hatch pattern for the top copper layer of the ground board of FIG. 6;

FIG. 8 illustrates the solid copper ground plane of the ground board of FIG. 6;

FIG. 9 illustrates another embodiment of the reduced size TM cylindrical shaped microstrip antenna which includes a GPS band stop filter;

FIG. 10 depicts an exploded view taken along line 10-10 of FIG. 9 of the GPS band stop filter; and

FIG. 11 is a plot illustrating the performance of the GPS band stop filter of FIG. 10 within the L-Band frequency range.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIGS. 1, 2 and 3, there is shown a reduced size TM cylindrical shaped microstrip antenna, designated generally by the reference numeral 20, which is adapted to transmit telemetry data from a weapons system, such as a missile, to a ground station or other receiving station. TM cylindrical shaped microstrip antenna 20 is designed to operate at a TM frequency band of 2210 MHz +/- 2.5 MHz. Microstrip Antenna 20 is a Linear Polarized microstrip antenna with wrap around capability for a five inch diameter projectile and is constrained to a width of 1.5 inches and a depth of 0.5 inches. The RF output signal from a single 50-ohm output coaxial SMMB connector results in microstrip antenna 20 producing a quasi-omni directional radiation pattern with the roll plane cut at -4 dBi (-4 decibels) or better. The overall length of microstrip antenna 20 is 15.515 inches and its overall width is 3.000 inches as shown in FIG. 2.

As depicted FIGS. 1, 2 and 3, TM cylindrical shaped microstrip antenna 20 has six antenna elements 22, 24, 26, 28, 30 and 32 which approximate a rectangle and have overall dimensions of 1.30" by 0.80". As shown in FIG. 1, antenna

elements 22, 24, 26, 28, 30 and 32 are aligned with one another are equally spaced apart from one another. Each of the antenna elements 22, 24, 26, 28, 30 and 32 are mounted on a dielectric layer 34 which has an approximate thickness of 0.020 of an inch. Each antenna element 22, 24, 26, 28, 30 and 322 is fabricated from etched copper, includes an elongated impedance matching slot 36 adjacent the lower edge of the antenna element 22, 24, 26, 28, 30 or 32 and a step-shaped tuning tab 40 which comprises the upper edge of each antenna element 22, 24, 26, 28, 30 and 32. The elongated opening 36 in each antenna element 22, 24, 26, 28, 30 and 32 is approximately 0.25 of an inch in length and operates to reduce the size of microstrip antenna 20 and assist in matching the antenna elements 22, 24, 26, 28, 30 and 32 to the antenna feed line of feed network 42 illustrated in FIG. 4. The step shaped tuning tabs 40 for each antenna element 22, 24, 26, 28, 30 and 32 allow the designer to fine tune microstrip antenna 20 to its operating frequency of 2210 MHz +/- 2.5 MHz. The antenna elements 22, 24, 26, 28, 30 and 32 transmit telemetry data via a microwave carrier signal/radio frequency (RF) signal to a ground station or other receiving station.

Dielectric substrate 34 (depicted in FIG. 1), which with the antenna elements 22, 24, 26, 28, 30 and 32 (depicted in FIG. 2), and the feed network 42 (depicted in FIG. 4) for

antenna comprises the circuit board 41 of microstrip antenna 20, has an upper portion 44 (depicted in FIG. 4) above antenna elements 22, 24, 26, 28, 30 and 32, and a lower portion 46 (depicted in FIG. 4) below antenna elements 22, 24, 26, 28, 30 and 32. The upper portion 44 and lower portion 46 of circuit board 41, which each have a width of 0.75 of an inch, are machined off during the fabrication process of microstrip antenna 20. When antenna 20 is fully assembled only the middle portion 48 of circuit board 41 remains. The middle portion 48 of circuit board 41 has a width of one inch.

At this time it should be noted that microstrip antenna 20 when mounted on a projectile has an overall length of 15.515 inches and a width of one inch. The cover board 39, the circuit board 41 and ground board 51 each have 0.75 inch wide section located at the top and bottom of the board machined off prior to mounting antenna 20 on a projectile.

As depicted in FIGS. 2 and 3, circuit board 41 also includes an etched copper cross hatch pattern 60 which is positioned around each of the antenna elements 22, 24, 26, 28, 30 and 32 and covers the remainder of the upper surface of dielectric layer 34. The etched copper cross hatch pattern 60 has 0.02 inch wide copper traces or strips 61 spaced apart by a 0.05 inch rectangular shaped opening 63 exposing the upper surface of dielectric layer 30. The 0.02 inch wide copper

traces/strips 61 and the 0.05 inch openings 63 are best depicted in FIG. 2.

As shown in FIG. 3, a dielectric gap 65 having a width of 0.05 of an inch is provided around the upper edge 40 and the sides 43 and 45 of antenna element 24 which separates the antenna element 24 from etched copper cross hatch pattern 60. Each of the other antenna elements 22, 26, 28, 30 and 32 each have a 0.05 inch dielectric gap around their upper edge and sides which separates the antenna element 22, 26, 28, 30 or 32 from copper cross hatch pattern 60.

At this time it should be noted that the exploded view of FIG. 3 illustrates in detail the copper cross hatch pattern 60 for the circuit board 41 of FIG. 1. As shown in FIG. 5, the bottom copper layer of circuit board 41 includes an etched copper cross hatch pattern 70 which is identical to the copper cross hatch pattern 60 on the top copper layer of circuit board 31. As shown FIG. 7, the top copper layer of a ground board 51 includes an etched copper cross hatch pattern 80 which is identical to and in alignment with copper cross hatch pattern 70 (illustrated in FIG. 5) on circuit board 41.

The copper cross hatch pattern 60 (illustrated in FIG. 3) of circuit board 41 operates as a solid ground plane to the microwave frequencies of the RF carrier signals transmitted by microstrip antenna 20 and also isolates the antenna elements

22, 24, 26, 28, 30 and 32 of microstrip antenna 20 from the antenna feed network 42 for antenna 20 which is mounted on the bottom surface of dielectric layer 34 below copper cross hatch pattern 60. Since the copper cross hatch pattern 60 exposes a substantial of dielectric substrate 30, there a high percentage of dielectric-to-dielectric bonding area available to secure dielectric layer 52 to a dielectric layer 37.

As shown in FIG. 1, the bonding film 64 between the bottom surface of dielectric layer 37 and the top surface of dielectric layer 34 secures dielectric layer 34 to dielectric layer 37. The bonding film 64 has a thickness of 0.002 of an inch. Dielectric layer 37 has a thickness of 0.005 of an inch and functions as the cover board 39 for microstrip antenna 20

The copper antenna elements 22, 24, 26, 28, 30 and 38 and ground plane cross hatch pattern 60 are specified as one ounce copper cladding. The one ounce copper cladding ground plane and antenna elements have a thickness of 0.0014 of an inch. Dielectric layers 34 and 35 each have a thickness of 0.02 of an inch. Dielectric layer 35 is the ground board 51 for microstrip antenna 20, and its bottom surface has a solid copper ground plane 66 affixed thereto. Copper ground plane 66, which is depicted in FIG. 8, has a thickness of 0.0014 of an inch. A 0.002 of an inch bonding film 68 secures dielectric layer 34 to dielectric layer 35.

At this time, it should be noted that the cover board 39, the circuit board 41 and the ground board 51 for the reduced size TM cylindrical shaped microstrip antenna comprising the present invention are fabricated using standard printed circuit board technology. The cover board which is dielectric layer 37 is fabricated from a laminate material RT/Duroid 5870 commercially available from Rogers Corporation of Rogers, Connecticut. The circuit board 41 and the ground board 51 are fabricated from a laminate material RT/Duroid 6002 also commercially available from Rogers Corporation.

Referring to FIGS. 2, 3, 4 and 5, the feed network 42 matches a 50 ohm input impedance to the antenna feed network input 72 which is located near the center of microstrip antenna 20. The feed network 42 distributes microwave signals to antenna elements 22, 24, 26, 28, 30 and 32 with equal amplitude and phase. The feed network 42, which includes a main transmission line 73 and a plurality of branch transmission lines 74, is configured such that the transmission line length from the antenna feed network input 72 to the antenna element feed terminal 76 is identical for each of the six antenna elements 22, 24, 26, 28, 30 and 32. This insures that the microwave signals transmitted by each of the antenna elements 22, 24, 26, 28, 30 and 32 are in phase and have equal amplitudes. A via or plated through hole 77 from the antenna

element feed terminal to the antenna element connects each antenna element 22, 24, 26, 28, 30 and 32 to its associated feed terminal 76. The main transmission line 76 and branch transmission lines 77 of feed network 42 are fabricated from etched copper.

Referring to FIGS. 1-5, the top layer of ground board 51 is a mirror image of the bottom layer of circuit board 41 except for feed network 42. When microstrip antenna 20 is fully assembled as shown in FIG. 6, cross hatch pattern 70 is in alignment with cross hatch pattern 80. This results in EM coupling of microwave signals between the circuit board 41 and ground board 51 even though there is a 0.002 thick bonding film 68 separating the two dielectric layers 34 and 35.

As shown in FIG. 6, dielectric substrate 35, which with the cross hatch pattern 80 and copper ground plane 66 comprises the ground board 51 of antenna 20, has an upper portion 82 above cross hatch pattern 80, a lower portion 84 and a middle portion 86. In a manner identical to the machining process for circuit board 41, the upper portion 82 and lower portion 84 of ground board 51, are machined off during the fabrication and assembly process for microstrip antenna 20. When microstrip antenna 20 is fully assembled only the middle portion 86 of ground board 51 remains. The middle portion 86 of ground board 51 has a width of one inch, while the upper portion 82 and

lower portion 84 of ground board 51 each have a width of 0.75 of an inch. In an identical manner, the upper portion and lower portion of the cover board 39 are machined off such the cover board 39 has an overall width of one inch.

As shown in FIGS. 4 and 5, the circuit board 41 includes approximately 270 copper plated through holes or vias 88 which are used to equalize potential on both sides of the circuit board 41. The copper plated through holes 88 are positioned at the edge of dielectric gap 65, along the lower edge 88 of each antenna elements 22, 24, 26, 28, 30 and 32 and also at the edge of the antenna feed network 42 for antenna 20.

Referring to FIGS. 4, 5, 6 and 7, the ground board 51 also includes approximately 270 copper plated through holes or vias 90 with each via 90 aligning one of the vias 88 of circuit board 41. As shown in FIGS. 6 and 7, the vias 90 are position around the edge of six rectangular shaped dielectric patches 91 within ground board 51 which align with the six antenna elements 22, 24, 26, 28, 30 and 32 and a dielectric area 93 within ground board 51 which aligns with the feed network 42 of circuit board 41. If too few vias 88 and 90 are included in the circuit board 41 and ground board 51, the antenna feed network 42 for antenna 20 becomes coupled to the antenna elements 22, 24, 26, 28, 30 and 32.

Referring to FIGS. 4, 5, 6 and 7, the layout of the bottom

surface of circuit board 41 is identical to the layout of the upper surface of ground board 51 except for the antenna feed network 42 on the bottom surface of ground board 51. This allows microwave signals to EM couple between dielectric layers 34 and 35 even though bonding film 68 separates dielectric layers 34 and 35. This unique feature of antenna 20 allows the vias 88 on circuit board 41 to couple to the vias 90 on ground board 51 thereby electrically connecting the circuit board 31 to copper ground plane 66 on the bottom surface of ground board 51.

Referring to FIGS. 9 and 10, there is shown another embodiment of the reduced size TM cylindrical shaped microstrip antenna array which includes a GPS Band Stop Filter, designated generally by the reference numeral 95. The GPS Band Stop Filter 95 is located on the bottom surface of circuit board 92 for the microstrip antenna. The microstrip antenna has eight rectangular shaped copper antenna elements 94, 96, 98, 100, 102, 104, 106 and 108 which transmit telemetry data within a TM frequency band of 2200-2300 MHz, resulting in a band width for the antenna of 100 MHz. The microstrip antenna's gain is approximately -6 dBi over 90% of its bandwidth.

Referring again to FIGS. 9 and 10, the feed network for the antenna matches a 50 ohm input impedance to the antenna feed network input 114 which is located near the center of the

microstrip antenna. The feed network distributes microwave signals to the eight antenna elements 94, 96, 98, 100, 102, 104, 106 and 108 with equal amplitude and phase. The feed network 42, which includes a main transmission line 111 and a plurality of branch transmission lines 110, is configured such that the transmission line length from the antenna feed network input 114 to the antenna element feed terminal 115 is identical for each of the eight antenna elements 94, 96, 98, 100, 102, 104, 106 and 108. This insures that the microwave signals transmitted by each of the antenna elements 94, 96, 98, 100, 102, 104, 106 and 108 are in phase and have equal amplitudes.

Referring to FIGS. 9, 10 and 11, the GPS band-stop filter 95 includes six etched copper open circuit stubs. As is best depicted in FIG. 10, three of the open circuit stubs 116A, 116B and 116C are connected to main transmission line 111 on one side of the main transmission line 111 in proximity to the antenna feed network input 114. There are also three additional open circuit stubs on the opposite side of the main transmission line 111 again in proximity to the antenna feed network input 114. Each of the open circuit stubs have an L-shape and translate to a short circuit within the filter's bandwidth. As is best illustrated by the plot 120 of FIG. 11, band stop filter 95 has a filter response of -60 dBi (-60 decibels) at approximately 1575 MHz which is within the GPS L-

Band frequency range. As can be seen from the plot 120 of FIG. 11, filter 50 is very effective at isolating telemetry data from GPS carrier signals. Plot 118 of FIG. 11 depicts the return loss for the microstrip antenna.

From the foregoing, it is readily apparent that the present invention comprises a new, unique and exceedingly useful TM cylindrical shaped microstrip antenna array for receiving telmetry signals which constitutes a considerable improvement over the known prior art. Many modifications and variations are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims that the invention may be practiced otherwise than as specifically described.